INTRODUCTION TO PERFORMANCE EXPECTATIONS

"The NGSS are standards, or goals, that reflect what a student should know and be able to do; they do not dictate the manner or methods by which the standards are taught. . . . Curriculum and assessment must be developed in a way that builds students' knowledge and ability toward the PEs [performance expectations]" (*Next Generation Science Standards*, 2013, page xiv).

This chapter shows how the NGSS Performance Expectations are bundled in the **Chemical Interactions Course** to provide a coherent set of instructional materials for teaching and learning. This chapter also provides details about how this FOSS course fits into the matrix of the FOSS Program (page 51). Each FOSS module K–5 and middle school course 6–8 has a functional role in the FOSS conceptual frameworks that were developed based on a decade of research on science education and the influence of *A Framework for K–12 Science Education* (2012) and *Next Generation Science Standards* (NGSS, 2013).

The FOSS curriculum provides a coherent vision of science teaching and learning in the three ways described by the NRC *Framework*. First, FOSS is designed around learning as a developmental progression, providing experiences that allow students to continually build on their initial notions and develop more complex science and engineering knowledge. Students develop functional understanding over time by building on foundational elements (intermediate knowledge). That progression is detailed in the conceptual frameworks.

Second, FOSS limits the number of core ideas, choosing depth of knowledge over broad shallow coverage. Those core ideas are addressed at multiple grade levels in ever greater complexity. FOSS investigations at each grade level focus on elements of core ideas that are teachable and learnable at that grade level.

Third, FOSS investigations integrate engagement with scientific ideas (content) and the practices of science and engineering by providing firsthand experiences.

Teach the course with the confidence that the developers have carefully considered the latest research and have integrated into each investigation the three dimensions of the NRC *Framework* and NGSS, and have designed powerful connections to the Common Core State Standards for ELA.

Contents

The NGSS Performance Expectations bundled in this course include

Physical Sciences

MS-PS1-1
MS-PS1-2
MS-PS1-3
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MS-PS1-6
MS-PS3-3
MS-PS3-4
MS-PS3-5

Engineering, Technology, and Applications of Science

MS-ETS1-1
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4

Disciplinary Core Ideas Addressed

The **Chemical Interactions Course** connects with the NRC *Framework* 6–8 grade band and the NGSS performance expectations for the middle school grades. The course focuses on core ideas for physical sciences primarily and engineering secondarily.

Physical Sciences

Framework core idea PS1: Matter and its interactions—How can one explain the structure, properties, and interactions of matter?

- **PS1.A: Structure and properties of matter**
  How do particles combine to form the variety of matter one observes? [All substances are made from some 100 different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with each other; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and vibrate in position but do not change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (Boundary: Predictions here are qualitative, not quantitative.)]

- **PS1.B: Chemical reactions**
  How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them? [Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others store energy.]

DISCIPLINARY CORE IDEAS

A Framework for K–12 Science Education has four core ideas in physical sciences.

- PS1: Matter and its interactions
- PS2: Motion and stability: Forces and interactions
- PS3: Energy
- PS4: Waves and their applications in technologies for information transfer

The questions and descriptions of the core ideas in the text on these pages are taken from the NRC *Framework* for grades 6–8 to keep the core ideas in a rich and useful context.

The performance expectations related to each core idea are taken from the NGSS for middle school.

The following NGSS grade 6–8 performance expectations for PS1 are derived from the Framework disciplinary core ideas above.

- **MS-PS1-1.** Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball-and-stick structures, or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete depiction of all individual atoms in a complex molecule or extended structure.]
- **MS-PS1-2.** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with HCl.] [Assessment Boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.]
- **MS-PS1-3.** Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [Assessment Boundary: Assessment is limited to qualitative information.]
- **MS-PS1-4.** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawings and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]

REFERENCES

National Research Council. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: National Academies Press, 2012.

NGSS Lead States. *Next Generation Science Standards: For States, by States.* Washington, DC: National Academies Press, 2013.

National Governors Association Center for Best Practices and Council of Chief State School Officers. *Common Core State Standards for English Language Arts and Literacy in History/Social Studies, Science, and Technical Subjects*. Washington, DC: authors, 2010.

- **MS-PS1-5.** Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.]
- **MS-PS1-6.** Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.]

Framework core idea PS3: Energy—How is energy transferred and conserved?

- **PS3.A: Definitions of energy**
  What is energy? [Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. A system of objects may also contain stored (potential) energy, depending on their relative positions. Stored energy is decreased in some chemical reactions and increased in others. The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and energy transfers by convection, conduction, and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures. Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.]
- **PS3.B: Conservation of energy and energy transfer**
  What is meant by conservation of energy? How is energy transferred between objects or systems? [When the motion energy of an object changes, there is inevitably some other change in energy at the same time. For example, the friction that causes a moving object to stop also results in an increase in the thermal energy in both surfaces; eventually heat energy is transferred to the surrounding

environment as the surfaces cool. The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation.]

The following NGSS grade 6–8 performance expectations for PS3 are derived from the Framework disciplinary core ideas above.

- **MS-PS3-3.** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]

  NOTE: This standard is also a main focus of the **FOSS Weather and Water Course**.

- **MS-PS3-4.** Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]

  NOTE: This standard is also a main focus of the **FOSS Weather and Water Course**.

- **MS-PS3-5.** Construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.]

  NOTE: This standard is also a main focus of the **FOSS Gravity and Kinetic Energy Course**.

DISCIPLINARY CORE IDEAS

A Framework for K–12 Science Education has two core ideas in engineering, technology, and applications of science.

ETS1: Engineering design

ETS2: Links among engineering, technology, science, and society

The questions and descriptions of the core ideas in the text on these pages are taken from the NRC *Framework* for grades 6–8 to keep the core ideas in a rich and useful context.

The performance expectations related to each core idea are taken from the NGSS for middle school.

Engineering, Technology, and Applications of Science

Framework core idea ETS1: Engineering design—How do engineers solve problems?

- **ETS1.A: Defining and delimiting an engineering problem**
  What is a design for? What are the criteria and constraints of a successful solution? [The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (e.g., familiarity with the local climate may rule out certain plants for the school garden).]
- **ETS1.B: Developing possible solutions**
  What is the process for developing potential design solutions? [A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. In any case, it is important to be able to communicate and explain solutions to others. Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the model based on peer and leader (e.g., teacher) feedback.]
- **ETS1.C: Optimizing the design solution**
  How can the various proposed design solutions be compared and improved? [There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Comparing different designs could involve running them through the same kinds of tests and systematically recording the results to determine which design performs best. Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. Once such a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful.]

The following NGSS grade 6–8 performance expectations for ETS1 are derived from the Framework disciplinary core idea above.

- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- **MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

SCIENCE AND ENGINEERING PRACTICES

A Framework for K–12 Science Education (National Research Council, 2012) describes eight science and engineering practices as essential elements of a K–12 science and engineering curriculum.

The learning progression for this dimension of the framework is addressed in *Next Generation Science Standards* (National Academies Press, 2013), volume 2, appendix F. Elements of the learning progression for practices recommended for grades 6–8 as described in the performance expectations appear in bullets below each practice.

Science and Engineering Practices Addressed

1. *Asking questions and defining problems*

- Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

2. *Developing and using models*

- Develop and/or use a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.
- Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

3. *Planning and carrying out investigations*

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- Evaluate the accuracy of various methods for collecting data.
- Collect data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

4. *Analyzing and interpreting data*

- Conduct analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- Analyze and interpret data to provide evidence for phenomena.
- Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
- Analyze and interpret data to determine similarities and differences in findings.

5. Using mathematics and computational thinking

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.
- Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.

6. Constructing explanations and designing solutions

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict and/or describe phenomena.
- Construct an explanation using models or representations.
- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.
- Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process, or system.
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

7. Engaging in argument from evidence

- Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

8. Obtaining, evaluating, and communicating information

- Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).
- Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.

- Communicate scientific and/or technical information (e.g., about a proposed object, tool, process, system) in writing and/or through oral presentations.

CROSSCUTTING CONCEPTS

A Framework for K–12 Science Education describes seven crosscutting concepts as essential elements of a K–12 science and engineering curriculum. The crosscutting concepts listed here are those recommended for grades 6-8 in the NGSS and are incorporated into the learning opportunities in the **Chemical Interactions Course**.

The learning progression for this dimension of the framework is addressed in volume 2, appendix G, of the NGSS. Elements of the learning progression for crosscutting concepts recommended for grades 6–8, as described in the performance expectations, appear after bullets below each concept.

Crosscutting Concepts Addressed

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
- Patterns in rates of change and other numerical relationships can provide information about natural and human-designed systems.
- Patterns can be used to identify cause-and-effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.

Cause and effect

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
- Cause-and-effect relationships may be used to predict phenomena in natural or designed systems.

Scale, proportion, and quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
- Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
- Phenomena that can be observed at one scale may not be observable at another scale.

Systems and system models

- Systems may interact with other systems; they may have subsystems and be a part of larger complex systems.
- Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems.

Energy and matter

- Matter is conserved because atoms are conserved in physical and chemical processes.
- Within a natural (or designed) system, the transfer of energy drives the motion and/or cycling of matter.

- Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion).
- The transfer of energy can be tracked as energy flows through a designed or natural system.

Structure and function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore complex natural and designed structures/systems can be analyzed to determine how they function.
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Stability and change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.
- Small changes in one part of a system might cause large changes in another part.
- Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.

CONNECTIONS

See volume 2, appendix H and appendix J, in the NGSS for more on these connections.

Connections to the Nature of Science

- **Scientific knowledge is based on empirical evidence.** Scientific knowledge is based upon logical and conceptual connections between evidence and explanations. Science disciplines share common rules of obtaining and evaluating empirical evidence.
- **Scientific investigations use a variety of methods.** Scientific investigations are guided by a set of values to ensure accuracy of measurements, observations, and objectivity of findings. Science depends on evaluating proposed explanations. Scientific values function as criteria in distinguishing between science and nonscience.
- **Science models, laws, mechanisms, and theories explain natural phenomena.** Theories are explanations for observable phenomena. Scientific theories are based on a body of evidence developed over time. Laws are regularities or mathematical descriptions of natural phenomena. A hypothesis is used by scientists as an idea that may contribute important new knowledge for the evaluation of a scientific theory. The term "theory" as used in science is very different from the common use outside of science.
- **Scientific knowledge assumes an order and consistency in natural systems.** Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. Science carefully considers and evaluates anomalies in data and evidence.
- **Science is a human endeavor.** Men and women from different social, cultural, and ethnic backgrounds work as scientists and engineers. Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination, and creativity. They are guided by habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. Advances in technology influence the progress of science, and science has influenced advances in technology.
- **Science addresses questions about the natural and material world.** Scientific knowledge is constrained by human capacity, technology, and materials. Science limits its explanations to systems that lend themselves to observation and empirical evidence. Scientific knowledge can describe consequences of actions but is not responsible for society's decisions.

Connections to Engineering, Technology, and Applications of Science

- **Influence of engineering, technology, and science on society and the natural world.** All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region.
- **Interdependence of science, engineering, and technology.** Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. Science and technology drive each other forward.

FOSS CONCEPTUAL FRAMEWORK

FOSS has conceptual structure at the course level. The concepts are carefully selected and organized in a sequence that makes sense to students when presented as intended. In the last half decade, research has focused on learning progressions. The idea behind a learning progression is that **core ideas** in science are complex and wide-reaching—ideas such as the structure of matter or the relationship between the distribution and function of organisms. From the age of awareness throughout life, matter and organisms are important to us. There are things we can and should understand about them in our primary school years, and progressively more complex and sophisticated things we should know about them as we gain experience and develop our cognitive abilities. When we as educators can determine those logical progressions, we can develop meaningful and effective curriculum.

FOSS has elaborated learning progressions for core ideas in science for kindergarten through grade 8. Developing the learning progressions involves identifying successively more sophisticated ways of thinking about core ideas over multiple years. "If mastery of a core idea in a science discipline is the ultimate educational destination, then well-designed learning progressions provide a map of the routes that can be taken to reach that destination" (National Research Council, *A Framework for K–12 Science Education*, 2012, page 26).

The FOSS modules (grades K–5) and courses (grades 6–8) are organized into three domains: physical science, earth science, and life science. Each domain is subdivided into two strands, each representing a core scientific idea, as shown in the columns in the table: matter/energy and change, atmosphere and Earth/rocks and landforms, structure and function/complex systems. The sequence of modules and courses in each strand relates to the core ideas described in the national framework. Modules at the bottom of the table form the foundation in the primary grades. The core ideas develop in complexity as they proceed up the columns.

In addition to the science content framework, every course provides opportunities for students to engage in and understand science practices, and many courses explore issues related to engineering practices and the use of natural resources.

The science content used to develop the FOSS courses describes what we want students to learn; the science and engineering practices describe how we want students to learn; and crosscutting concepts stitch the whole effort into a coherent fabric describing the whole natural world. Practices involve a number of habits of mind and philosophical orientations, and these, too, will develop in richness and complexity as students advance through their science studies. Science and engineering practices involve behaviors, so they can be best assessed while in progress. Thus, assessment of practices is based on teacher observation. The indicators of progress include students involved in the many aspects of active thinking, students motivated to learn, and students taking responsibility for their own learning.

FOSS Next Generation—K–8 Sequence

	PHYSICAL SCIENCE		EARTH SCIENCE		LIFE SCIENCE	
	MATTER	ENERGY AND CHANGE	ATMOSPHERE AND EARTH	ROCKS AND LANDFORMS	STRUCTURE/ FUNCTION	COMPLEX SYSTEMS
6–8	Waves; Gravity and Kinetic Energy Chemical Interactions Electromagnetic Force		Planetary Science Earth History Weather and Water		Heredity and Adaptation Populations and Ecosystems Diversity of Life; Human Systems Interactions	
5	Mixtures and Solutions		Earth and Sun		Living Systems	
4		Energy		Soils, Rocks, and Landforms	Environments	
3	Motion and Matter		Water and Climate		Structures of Life	
2	Solids and Liquids			Pebbles, Sand, and Silt	Insects and Plants	
1		Sound and Light	Air and Weather		Plants and Animals	
K	Materials and Motion		Trees and Weather		Animals Two by Two	

BACKGROUND FOR THE CONCEPTUAL FRAMEWORK
in Chemical Interactions

Matter Interactions

In this course we open the chemical treasure chest just a crack and invite students to look in. Chemistry is arguably the study of everything. The study of chemistry stems from three fundamental questions.

- What is matter (everything tangible) made of?
- In what ways and under what circumstances does matter change?
- How do we know?

The first question addresses one of the grand ideas in science. Students in middle school have notions of atoms—everything is made of atoms. That bit of information enters our general knowledge formally or informally during the elementary years. But now students will learn to understand the immense diversity of objects and materials in terms of a few different kinds of atoms in combination—a huge idea.

We live in a dynamic universe. The one certain thing is change. To answer the second question, students grapple with the difficult ideas of matter transformation and energy. Some things that students know from everyday experience, such as water changes to ice in the freezer, and chocolate melts in the sunshine, are challenging to analyze and explain. Pursuing melting and freezing opens the door to the kinetic theory of atoms—atoms are always in motion. The amount of motion of the microscopic, invisible particles that constitute a sample of matter determines its macroscopic properties. So students must develop an intellectual model for the behavior of objects that cannot be observed directly. Also, when samples of two different kinds of matter are mixed, it is possible that they will transform into new forms of matter. Students can observe this process directly—we had these substances at the start, and we have these different substances now. The process is called a chemical reaction, and it produces all the substances in the world.

These two ideas, the constant motion of atoms and their combinations, and the reorganization of atoms to form new substances, provide us with a vision of an orderly universe in which atoms behave in predictable ways guided by rules of engagement. These core ideas are deep, requiring years to understand thoroughly.

CONCEPTUAL FRAMEWORK
Physical Sciences, Matter: Chemical Interactions

Matter Has Structure

Concept A Matter exists in three states (solid, liquid, and gas), which have observable properties.

- Matter exists on Earth in three common phases (states)—solid, liquid, and gas.
- In a gas, particles are widely spaced and in constant motion.
- In a liquid, particles are constantly in contact and are able to move around and over one another.
- In a solid, particles are closely spaced and may vibrate in position but do not change relative locations.

Concept B Matter has physical properties that can be observed and quantified.

- Gas is matter—it has mass and occupies space. There is nothing between gas particles except empty space.
- During compression, contraction, and expansion, the number and character of particles in a sample of gas do not change; the space between the particles does change.
- A substance is matter with a unique composition and distinct physical and chemical properties that can be used to identify it.

Concept C Matter is made of particles too small to see.

- An element is a basic substance that cannot be broken into a simpler substance. Atoms are the fundamental particles of elements.
- All substances are made from some 100 different types of atoms, which combine with one another in various ways.
- The periodic table of the elements displays all the naturally occurring and synthesized elements.

Matter Interacts

Concept A Mass of material is conserved.

- Atoms are neither created nor destroyed during chemical reactions, only rearranged.

Concept B Change of temperature can produce changes in physical state.

- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.
- Energy transfer to/from the particles in a substance can result in phase change.

(continued on page 55)

Developing Scientific Thinking

This brings us to the third question, which is perhaps the most important one. Contemplating your own mental constructs that constitute knowing and understanding is an important metacognitive process that flourishes in the middle school years. Internal questioning, reviewing, revising, confirming, and explaining is part of the healthy, responsible processing of complex ideas.

We have found that students struggle with the nomenclature of atomic relationships. There are 90 elements occurring naturally on Earth, each represented by a unique atom. Atoms can combine with other atoms to form particles that define a substance. If the combination has only one kind of atom, the substance is an element. If the combination has two or more kinds of atoms, the substance is a compound. If two or more atoms (same kind or different) that define a substance are connected with covalent bonds, the particle is called a molecule. If the combination of atoms includes an ionic bond, there is no particle defining the substance, and the substance is an ionic compound. Get the picture? Very complicated for the neophyte.

The nomenclature is simplified in the **Chemical Interactions Course**. We introduce the elements first, and students get to know them as a family of fundamental substances. The periodic table of the elements is the family tree used to develop familiarity. Much later the atom is introduced as the basic and unique representative of each element. Atoms combine to form compounds, which define most of the substances on Earth. We do not develop the ideas of bonds, ions, or molecules in great depth. The basic formulaic unit of a substance, such as H_2O (water), NaCl (sodium chloride), and O_2 (oxygen gas), is generally referred to as the basic particle of the substance.

Engineering Design

Science is a discovery activity, a process for producing new knowledge. Scientific knowledge advances when scientists observe objects and events, think about how their observations relate to what is known, test their ideas in logical ways, and generate explanations that integrate the new information into understanding of the natural world. Thus the scientific enterprise is both what we know (content knowledge) and how we come to know it (practices). Scientists engage in a set of practices as they do their work, and these are the same practices students use in their science investigations.

(continued from page 53)

- During phase change, the number of particles does not change, rather the relationship between particles changes.
- The temperatures at which phase changes occur are different for different substances.

Concept C During physical interactions, substances form mixtures in which the interacting substances retain their original properties.

- A mixture is a combination of two or more substances.
- Dissolving occurs when one substance (solute) is reduced to particles and is distributed uniformly throughout the particles of a second substance (solvent).

Concept D During chemical interactions, starting substances (reactants) change into new substances (products).

- During a chemical reaction, the atoms of substances (reactants) rearrange to form new substances (products).
- Some chemical reactions release energy; others store energy.

Energy Transfer and Conservation

Concept A Energy is a quantitative property (condition) of a system that depends on the motion and interactions of matter and radiation within the system.

- Kinetic energy is energy of motion.
- Temperature is a measure of the average kinetic energy of particles of matter.
- Matter expands when the kinetic energy of its particles increases (warms); matter contracts when the kinetic energy of its particles decreases (cools).

Concept B The total change of energy in any system is always equal to the total energy transferred into or out of the system. When two objects interact, each one exerts a force on the other, and these forces can transfer energy.

- Energy is conserved. Energy is not created or destroyed. The amount of energy in a system is always equal to the total energy transferred into or out of the system.
- In science, "heat" refers to the transfer of thermal energy due to the temperature difference between two objects.
- Energy always transfers from particles with more kinetic energy to particles with less kinetic energy.

Engineers apply that understanding of the natural world to solve real-world problems. Engineering is the systematic approach to finding solutions to problems identified by people in societies. The fields of science and engineering are mutually supportive, and scientists and engineers collaborate in their work. Often, acquiring scientific data requires designing and producing new technologies—tools, instruments, machines, and processes—to perform specific functions. The practices that engineers use are very similar to science practices, but also involve defining problems and designing solutions.

The process of engineering design, while it involves engineering practices, is considered a separate set of disciplinary core ideas in the NRC *Framework* and in the NGSS. There are three basic ideas of engineering design: defining the problem, developing possible solutions, and improving the design.

Defining the problem "with precision" means having a clear understanding of specific criteria and constraints in a complex problem that might have a broader societal or environmental impact.

Developing possible solutions at middle school focuses not only on generating design ideas but also on a process of evaluating different ideas that have been proposed in a systematic way, such as a trade-off matrix to determine the most promising designs. Those most promising designs would be tested, and solution results would be combined in a new solution.

Optimizing the design involves an iterative process of testing the best design, systematically analyzing the results, modifying the design while controlling variables, retesting, comparing results, and again modifying the design. Students may go through this cycle several times to optimize a design. Students need to know that failure is not only OK, but expected, in engineering design. Having something fail drives you to improve the system and make progress.

Collaboration is an important aspect of engineering design; learning from the successes and failures of other design groups can be very productive. In Investigation 6, students extensively explore the disciplinary core ideas of engineering design in the context of energy transfer through an iterative process of design. However, students can engage in engineering practices without fully engaging in the iterative process, as they do in other investigations in this course. FOSS has a continuum of engagement in the engineering practices and process, from short experiences to more in-depth experiences where students reflect on core ideas about the design process.

CONCEPTUAL FRAMEWORK

Engineering Design: Chemical Interactions

Concept A Defining and delimiting engineering problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions.

Concept B Developing possible solutions

- A solution needs to be tested and then modified on the basis of the test results, in order to improve it.
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.
- Models of all kinds are important for testing solutions.

Concept C Optimizing the design solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Physical Science Content Sequence

This table shows the five FOSS modules and courses that address the content sequence "Matter" for grades K–8. Running through the sequence are the two main content progressions—matter has structure and matter interacts. The supporting elements in these modules (somewhat abbreviated) are listed. The elements for the **Chemical Interactions Course** are expanded to show how they fit into the sequence.

	MATTER	
Module or course	**Matter has structure**	**Matter interacts**
Chemical Interactions (middle school)		
Mixtures and Solutions (grade 5)	• Solid matter can break into pieces too small to see. • Mass is conserved (not created or lost) during changes. • Properties can be used to identify substances (e.g., solubility). • Relative density can be used to seriate solutions of different concentrations.	• A mixture is two or more intermingled substances. • Dissolving occurs when one substance disappears in a second substance. • A chemical reaction occurs when substances mix and new products result. • Melting is an interaction between one substance and heat.
Motion and Matter (grade 3)	• Properties of matter (solid, liquid, gas) can be described using measurement (length, mass, volume, temperature). • Measurement can be used to confirm that the whole is equal to its parts.	• Different substances change state (e.g., melt or freeze) at different temperatures. • Mass is conserved when objects or materials are mixed.
Solids and Liquids (grade 2)	• Common matter is solid, liquid, and gas. • Solid matter has definite shape. • Liquid matter has definite volume. • Gas matter has neither definite shape nor volume and expands to fill containers. • Intrinsic properties of matter can be used to organize objects (e.g., color, shape).	• Solids interact with water in various ways: float, sink, dissolve, swell, change. • Liquids interact with water in various ways: layer, mix, change color. • Substances change state (e.g., melt or freeze) when heated or cooled.
Materials and Motion (grade K)	• Wood, paper, rock, and fabric are examples of solid materials. • Solid objects are made of solid materials. • Solid objects have properties. • The whole (object) can be broken into smaller pieces.	• Wood, paper, and fabric can be changed by sanding, coloring, tearing, etc. • Common materials can be changed into new materials (paper making, weaving, etc.).

Chemical Interactions

Matter has structure	Matter interacts
• Matter is made of atoms. • Substances are defined by chemical formulas. • Elements are defined by unique atoms. • The properties of matter are determined by the kinds and behaviors of its atoms. • Atomic theory explains the conservation of matter.	• During chemical reactions, particles in reactants rearrange to form new products. • Energy transfer to/from the particles in a substance can result in phase change. • During dissolving, one substance is reduced to particles (solute), which are distributed uniformly throughout the particles of the other substance (solvent). • Scientists and engineers can synthesize new materials using chemical interactions.

NOTE

See the Assessment chapter in this *Investigations Guide* for more details on how the FOSS embedded and benchmark assessment opportunities align to the conceptual framework and the learning progressions. In addition, the Assessment chapter describes specific connections between the FOSS assessments and the NGSS performance expectations.

The NGSS Performance Expectations addressed in this course include

Physical Sciences

MS-PS1-1
MS-PS1-2
MS-PS1-3
MS-PS1-4
MS-PS1-5
MS-PS1-6
MS-PS3-3
MS-PS3-4
MS-PS3-5

Engineering, Technology, and Applications of Science

MS-ETS1-1
MS-ETS1-2
MS-ETS1-3
MS-ETS1-4

See pages 38–43 in this chapter for more details on the Grades 6–8 NGSS performance expectations.

CONNECTIONS TO NGSS BY INVESTIGATION

Inv. 1: Substances

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Planning and carrying out investigations Analyzing and interpreting data Constructing explanations Engaging in argument from evidence Obtaining, evaluating, and communicating information	**Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS1.A: Structure and properties of matter • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **(MS-PS1-2, MS-PS1-3)**	**PS1.B: Chemical reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. **(MS-PS1-2, MS-PS1-3, MS-PS1-5)**	Patterns Cause and effect

Inv. 2: Elements

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Developing and using models Constructing explanations Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite evidence to support analysis of science and text. 2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 5. Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. 10. Read and comprehend science independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. 9. Draw evidence from informational texts to support analysis, reflection, and research.. **Speaking and Listening** 1. Engage in collaborative discussions. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS1.A: Structure and properties of matter • Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. **(MS-PS1-1)** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **(MS-PS1-2, MS-PS1-3)**		Patterns Scale, proportion, and quantity Systems and system models Structure and function

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Asking questions Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations Engaging in argument from evidence Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite evidence to support analysis of science texts. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. 10. Read and comprehend science texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS1.A: Structure and properties of matter • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **(MS-PS1-2, MS-PS1-3)** • Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. **(MS-PS1-4)** • In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. **(MS-PS1-4)**	**PS1.B: Chemical reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. **(MS-PS1-2, MS-PS1-3, MS-PS1-5)**	Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Stability and change

Inv. 4: Kinetic Energy

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Constructing explanations Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite evidence to support analysis of science texts. 2. Determine the central ideas of a text. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 10. Read and comprehend science texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. **Speaking and Listening** 1. Engage in collaborative discussions. **Language** 4. Determine or clarify meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS1.A: Structure and properties of matter • Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. **(MS-PS1-4)** • In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. **(MS-PS1-4)** • The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. **(MS-PS1-4)**	**PS3.A: Definitions of energy** • Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **(secondary to MS-PS1-4)** • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amount of matter present. **(MS-PS3-3, MS-PS3-4)** **PS3.B: Conservation of energy and energy transfers** • When the motion energy of an object changes, there is inevitably some other change in energy at the same time. **(MS-PS3-5)**	Cause and effect Systems and system models Energy and matter

Inv. 5: Energy Transfer

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite evidence to support analysis of science texts. 2. Determine the central ideas or conclusions of a text. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. 10. Read and comprehend science texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS3.A: Definitions of energy • The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). In science, heat is used only for this second meaning; it refers to energy transferred when two objects or systems are at different temperatures. **(secondary to MS-PS1-4)** • Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **(secondary to MS-PS1-4)** • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amount of matter present. **(MS-PS3-3, MS-PS3-4)**	**PS3.B: Conservation of energy and energy transfer** • When the motion energy of an object changes, there is inevitably some other change in energy at the same time. **(MS-PS3-5)** • The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. **(MS-PS3-4)** • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. **(MS-PS3-3)**	Patterns Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change

Inv. 6: Thermos Engineering

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions Engaging in argument from evidence Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 2. Determine the central ideas or conclusions of a text. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. 10. Read and comprehend science texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. 5. Develop and strengthen writing. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 1. Engage in collaborative discussions. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning. 6. Acquire and use academic and domain-specific words and phrases.

FOSS

Disciplinary Core Ideas		Crosscutting Concepts
PS3.A: Definitions of energy • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **(MS-PS3-3, MS-PS3-4)** **PS3.B: Conservation of energy and energy transfer** • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. **(MS-PS3-3)**	**ETS1.A: Defining and delimiting engineering problems** • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. **(MS-ETS1-1)** **ETS1.B: Developing possible solutions** • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. **(MS-ETS1-4)** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. **(MS-ETS1-2, MS-ETS1-3)** • Models of all kinds are important for testing solutions. **(MS-ETS1-4)** **ETS1.C: Optimizing the design solution** • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. **(MS-ETS1-3)** • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. **(MS-ETS1-4)**	Patterns Cause and effect Systems and system models Energy and matter Structure and function

Inv. 7: Solutions

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite evidence to support analysis of science texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary. 4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases. 6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. 10. Read and comprehend science texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 1. Engage in collaborative discussions. 5. Include visual displays in presentations. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS1.A: Structure and properties of matter • Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. **(MS-PS1-1)** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **(MS-PS-1-2, MS-PS1-3)** • In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. **(MS-PS1-4)**	**PS3.A: Definitions of energy** • Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **(secondary to MS-PS1-4)** • Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **(MS-PS3-3, MS-PS3-4)**	Patterns Cause and effect Scale, proportion, and quantity Systems and system models

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions Engaging in argument from evidence Obtaining, evaluating, and communicating information	**Reading—Literacy in Science and Technical Subjects** 1. Cite evidence to support analysis of science texts. 2. Determine the central ideas or conclusions of a text; provide an accurate summary. 5. Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic. 7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. 10. Read and comprehend science texts independently and proficiently. **Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing. 5. Develop and strengthen writing. 8. Gather relevant information from multiple print and digital sources. 9. Draw evidence from informational texts to support analysis, reflection, and research. **Speaking and Listening** 1. Engage in collaborative discussions. 5. Include visual displays in presentations. **Language** 4. Determine or clarify the meaning of unknown words or phrases. 5. Demonstrate understanding of word relationships and nuances in word meaning. 6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS1.A: Structure and properties of matter • In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. **(MS-PS1-4)** • The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. **(MS-PS1-4)** **PS1.B: Chemical reactions** • Some chemical reactions release energy, others store energy. **(MS-PS1-6)** **PS3.B: Conservation of energy and energy transfer** • The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. **(MS-PS3-4)**	**ETS1.B: Developing possible solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. **(MS-ETS1-2, MS-ETS1-3)** • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. **(MS-ETS1-3)** **ETS1.C: Optimizing the design solution** • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. **(MS-ETS1-3)** • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. **(MS-ETS1-4)**	Patterns Cause and effect Systems and system models Energy and matter Structure and function Stability and change

Science and Engineering Practices

Developing and using models
Planning and carrying out investigations
Analyzing and interpreting data
Using mathematics and computational thinking
Constructing explanations
Engaging in argument from evidence
Obtaining, evaluating, and communicating information

Connections to Common Core State Standards—ELA

Reading—Literacy in Science and Technical Subjects

1. Cite evidence to support analysis of science texts.
2. Determine the central ideas or conclusions of a text; provide an accurate summary.
4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases.
7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.
9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
10. Read and comprehend science texts independently and proficiently.

Writing—Literacy in Science and Technical Subjects

4. Produce clear and coherent writing.
7. Conduct short research projects to answer a question.
8. Gather relevant information from multiple print and digital sources.
9. Draw evidence from informational texts to support analysis, reflection, and research.

Speaking and Listening

2. Analyze the purpose of information presented in diverse media and formats and evaluate the motives behind its presentation.

Language

4. Determine or clarify the meaning of unknown words or phrases.
5. Demonstrate understanding of word relationships and nuances in word meaning.
6. Acquire and use academic and domain-specific words and phrases.

Disciplinary Core Ideas		Crosscutting Concepts
PS1.A: Structure and properties of matter • Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. **(MS-PS1-1)** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **(MS-PS1-2, MS-PS1-3)**	**PS1.B: Chemical reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. **(MS-PS1-2, MS-PS1-3, MS-PS1-5)** • The total number of each type of atom is conserved, and thus the mass does not change. **(MS-PS1-5)**	Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function

Inv. 10: Limiting Factors

Science and Engineering Practices	Connections to Common Core State Standards—ELA
Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations Obtaining, evaluating, and communicating information	**Writing—Literacy in Science and Technical Subjects** 4. Produce clear and coherent writing.

Disciplinary Core Ideas		Crosscutting Concepts
PS1.A: Structure and properties of matter • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **(MS-PS1-2, MS-PS1-3)**	**PS1.B: Chemical reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. **(MS-PS1-2, MS-PS1-3, MS-PS1-5)** • The total number of each type of atom is conserved, and thus the mass does not change. **(MS-PS1-5)**	Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Stability and change

RECOMMENDED FOSS NEXT GENERATION K–8 SCOPE AND SEQUENCE

Grade	Integrated Middle Grades				
6–8	Heredity and Adaptation*	Electromagnetic Force*	Gravity and Kinetic Energy*	Waves*	Planetary Science
	Chemical Interactions		Earth History		Populations and Ecosystems
	Weather and Water		Diversity of Life		Human Systems Interactions*

*Half-length courses — Physical Science content — Earth Science content — Life Science content — Engineering content

Grade	Physical Science	Earth Science	Life Science
5	Mixtures and Solutions	Earth and Sun	Living Systems
4	Energy	Soils, Rocks, and Landforms	Environments
3	Motion and Matter	Water and Climate	Structures of Life
2	Solids and Liquids	Pebbles, Sand, and Silt	Insects and Plants
1	Sound and Light	Air and Weather	Plants and Animals
K	Materials and Motion	Trees and Weather	Animals Two by Two